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SOME REMARKS ON THE MULTIVERSE CONCEPT

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Abstract

The aim of the paper is to put some criticism into the multiverse idea. Such a criticism is especially necessary when the considered topic evades empirical control. We critically asses some "recipes" to produce "other universes". Some of them seem to be in contrast with the claim that the final theory of physics should be "rigid" in the sense that any perturbation of its parameters or values of its physical constants would entirely ruin the theory. There are two concepts that are involved in almost all speculations concerning the multiverse, namely the concept of probability and the concept of infinity. We analyze them in turn. The crucial point is whether the multiverse hypothesis is empirically falsifiable or not. We show that the positive answer to this question is often based on a false understanding of the falsifiability criterion.

1 Introductory Remarks

The idea that our universe is but a member of a vast (possibly infinite) family of "other universes" has recently become fashionable. The motivation behind this fashion is correctly expressed by Martin Rees:

> "The physical laws 'laid down' in the big bang seem to apply everywhere we can now observe. But though they are unchanging (or almost so), they seem rather specially adjusted. This could be a coincidence: I used to think so. But an enlarged cosmological perspective suggests an interpretation that seems compellingly convincing. There may be other universes - uncountable many of them - of which ours is just one. In the others, the laws and constants are different. But ours is not randomly selected. It belongs to the unusual subset that allow complexity and consciousness to develop. Once we accept this, the seemingly 'designed' or 'fine-tuned' features of our universe need occasion no surprise" [6, p. 250-251].

The set of all universes is often called the "multiverse". The following remarks are intended to put some criticism into this idea. Such a criticism is especially necessary if a concept we are dealing with does not remain under the empirical control, and this is exactly the case as far as the multiverse concept is considered.

I shall first consider various methods used to produce "other universes" (section 2), and then the relationship between the multiverse concept and the idea of the final physical theory (Theory of Everything - TOE) (section 3). There are two other concepts that are crucially involved in almost all speculations concerning the multiverse - the concept of probability and the concept of infinity. I consider them in sections 4 and 5, respectively. And last but not least, the question is put into focus of whether the criterion of falsifiability can be applied to the multiverse doctrine. Several authors claim that at least in some sense the answer to this question should be "yes". It seems, however, that they miss the point as far as the standard meaning of this criterion is concerned. This is considered in section 6.

2 How to Produce Other Universes?

There are several ways of producing “other universes”:

(a) by varying initial conditions or other parameters characterizing the universe;

(b) by changing values of fundamental constants;

(c) by regarding each solution of some cosmological equations (typically, Einstein’s equations) as describing a certain universe;

(d) by realistically treating the Everett-Wheeler type interpretation of quantum mechanics; or

(e) by changing physical laws themselves.

These methods are not exhaustive; one could invent more ways of producing other worlds (see, for instance, [8]). The difference between various recipes is not clear-cut. On the one hand, initial conditions select a particular solution to a cosmological equation, and in this sense can be identified with this solution. On the other hand, initial conditions and parameters characterizing the universe can be implied by physical laws, and thus be not regarded as essentially different from them. Moreover, there exists a tendency in cosmology to construct a world model that would need no initial conditions at all or in which initial conditions would be uniquely determined by the laws of physics. One can also imagine a situation in which the initial conditions, as referring to the entire universe, simulate physical laws.

Various mechanisms were proposed to produce the multiverse according to recipe (a), (b) and (e); for instance, via Linde’s chaotic inflation, via Smolin’s world generation in gravitational collapse, etc.

There is still another meaning of the term “multiverse” (close to the one produced with the help of method (c)) which is not only acceptable, but is implicit in every cosmological investigation. Cosmology is often accused of being rather peculiar science since the object of its investigation is unique. The universe is given to us in a single copy, whereas it seems essential for the empirical method to have many instances of the same type. Let us take a closer look at this objection. The laws of physics are usually formulated in terms of differential equations, which from their very nature describe a structure composed of a net of relations between quantitative properties common to phenomena of a given type. Individual characteristics of every phenomenon are accounted for by selecting suitable initial or boundary conditions. This strategy applies equally well to cosmology.

One tries to find all solutions to a cosmological equation, and then to identify those initial or boundary conditions that select the subclass of solutions best approximating the universe we actually observe. By doing so we place our universe, as it were, in the environment of other universes. Herman Bondi once wrote that

> "the uniqueness of the actual universe makes it impossible to distinguish, on purely observational grounds, between its general and its peculiar features even if such a distinction were logically tenable" [2, p. 9-10].

In fact, in cosmology we make this distinction by comparing our universe with other members of the multiverse (in the above sense; for more see [4]).

It is worthwhile to notice that this strategy is implicit in the experimental method itself. Because of unavoidable measurement errors we never consider a single theoretical model, as being in agreement with empirical data, but rather a class of such models (i.e., solutions to cosmological equations) that fit into the "box of measurement errors". In this sense, the multiverse (as the set of solutions to cosmological equations) must be taken into account in order to render the science of the universe possible. This is a purely methodological procedure that does not require believing that all these universes do really exist.

3 Is the Structure of the Universe Rigid?

Methods (a) and (b) are based on a tacit assumption that if one perturbs initial conditions of cosmological equations, one will obtain another well functioning "copy" of the cosmic evolution, and that if one changes the value of a physical constant, one would obtain another equally admissible universe. This is a questionable assumption. It seems to be in contrast with a trend well rooted in the modern history of physics — a trend towards unity. Theoreticians who look for the Theory of Everything (TOE) often claim that there could exist only one logically admissible theory of this kind. It would not admit any competition; every perturbation of such a theory would destroy it completely. In this sense, such a theory would be a necessary theory.

Having in mind Gödel's incompleteness theorem (and other so-called limiting theorems), it could seem that the above idea is too demanding. It is true that consequences of Gödel type theorems for physics are not clear [5]. However, I would guess that even if these theorems impose some limitations on physics, the laws of physics enjoy maximally admissible degree of logical consistency. If this is so, it would be rather difficult to perturb the mathematical structure of the universe without damaging it in a serious way.

We could put these rather vague ideas into the following quasi-formal wording. Let us consider the process of "reducing" theory T1 to a theory T2, for instance by going with the value of a parameter k to a certain "limiting value". If we consider the reverse process, we can say that the theory T2 is deformed into the theory T1 with k as its deformation parameter. For certain mathematical structures the deformation procedure can be strictly defined (usually, deformation is not unique). Roughly speaking, a structure is said to be rigid, with respect to a certain deformation parameter, if every its deformation, with respect to this parameter, yields again the same structure (see, for instance, [3, 7]).

By using this terminology one could demand from TOE that its mathematical structure should be rigid with respect to all its possible deformation parameters. If we elevate this to the rank of a principle, it seems to work against the multiverse idea: we cannot change at will fundamental constants or some other parameters characterizing the universe without fatally damaging TOE. However, we should take into account a more complex possibility. As noticed by Rees,

> "the multiverse may be governed by some unified theory, but each universe may cool down in a fashion that has 'accidental' features, ending up governed by different laws (and with different physical constants) from others members of the ensemble" [6, p. 226].

Whether such a scenario is possible would of course depend on the future "unified theory" (TOE) and the "degree of its rigidity". So far both the multiverse idea and TOE belong to faraway outskirts of science rather than to science itself, but when speculating about the multiverse idea one should take into account that TOE could impose on it severe limitations or even completely exclude some of its versions.

I restrain myself from commenting on recipes (d) and (e). The former would lead us into the vast field of quantum mechanics interpretations, an if we admit the latter, everything is possible.

4 From a Minor Nuisance into a Major Embarrassment

"As multiverse theories gain credence, the sticky issue of how to compute probabilities in physics is growing from a minor nuisance into a major embarrassment" [8]. This Tegmark's remark is even truer than one could guess at the first glance. In fact, almost all arguments concerning the multiverse are of probabilistic type, and all of them presuppose that there exists a probability measure on the set of all possible initial conditions (or at least on some of its subsets), or on the ensemble of universes (or at least on some of its subensembles). This leads to a difficult mathematical problem that, in all its generality, remains unsolved.

There are strong reasons to believe that we have discovered but a tiny fraction of all possible mathematical structures. Many structures we actually know can be generalized in many ways (in fact, the unification of physics proceeds by adopting more and more general structures to model the world). In this respect, no mathematical structure we know can *a priori* be regarded as an "absolute" one, in the sense that it could not be reduced to a special instant of a more general structure. This refers also to the theory of probability (with all its applications and ramifications, such as: statistics, stochastics, randomicity...). The multiverse idea tacitly assumes that the present probability theory is "absolute", i.e., that what can be deduced with the help of it is decisive. One could truly say that the standard probability theory reigns over all our explorations of the multiverse. Indeed, our speculations on the multivesre are but different variations of playing probability games. If looking at cosmology from within of our universe (without taking into account other universes) is a frog perspective (Tegmark's expression), then treating any of the known mathematical structures (probability theory included) as absolute (unless it has been proved to be rigid in some sense) merits the name of a worm perspective.

In fact we already know a powerful generalization of the standard probability theory that could serve as a warning against treating present probabilistic concepts as final ones. I have in mind the noncommutative theory of probability (see, for instance, [1, 9]. Noncommutativity introduces new, and often unexpected, possibilities into the probabilistic vision. To see this it is enough to remember that the standard concept of probability refers to "statistical ensembles" (i.e., collections of individuals), whereas noncommutative spaces are, in general non-local, i.e., the concepts such as those of a point and its neighborhood are meaningless in them. No wonder that in the noncommutative probability theory the concepts appear that do not exist in the commutative context. The typical example is the concept of freeness. Although it plays a similar role to independence in the commutative case, it by no means can be reduced to it (noncommutative theory of probability is also called free probability theory).

To see how the noncommutative probability theory works let us consider the following example. In quantum mechanics it is often important to compute the spectrum of the sum $A + B$ of two hermitian matrices A and B the spectra of which are known. The problem is difficult. However, when the rank of the matrices becomes large, an unexpected phenomenon occurs. In such a case, we can bet, with a great chance to win, that for almost all choices of the matrices A and B the spectrum of the sum $A + B$ is the same, and can be approximated with the help of a "noncommutative probability measure" [1]. This is a clear indication that in a non-familiar context we must be ready to meet unexpected probability behavior.

5 Paradoxes of Infinity

It is known that infinity generates paradoxes. In cosmology they are especially troubling. If the universe extends to infinity or if there is an infinite number of various universes, the paradoxes are not only a mental game but could have an impact on what really happens. Tegmark writes:

> "If space is infinite and the distribution of matter is sufficiently uniform on large scales, then even the most unlikely events must take place somewhere. In particular, there are infinitely many other inhabited planets, including not just one but infinitely many with people with the same appearance, name and memories as you" [8].

The theoretical basis for this speculations is the ergodic character of the initial conditions for the universe. This means that the probability distribution of outcomes in a given volume within the multiverse is the same as that for different volumes in a single universe, provided that each member-world of the multiverse results from random initial conditions. This implies that — as expressed by Tegmark — "everything that could in principle have happened here did in fact happen somewhere else". According to his "extremely conservative estimate", in the infinite universe "the closest identical copy of you is about $10^{10^{29}}$ m away" [8].

The following "caveats" should be formulated concerning these speculations:

- They are based on the standard concept of probability (with the additional assumption that we have at our disposal a suitable probability measure on the ensemble of universes), and it is by no means certain that this concept refers to all levels of physical reality.

- They are based on a naive concept of infinity. Infinity should not be treated as a "very, very big number", but rather as something very different from all numbers. Having this in mind one should be at least less self-confident when speaking about infinities in cosmology than it often actually happens.

- One should not exclude that on the higher organization level (such as intelligent life) a certain "individualization principle" could be at work, preventing any "multiplication" of the same individuum. We should not forget that, for instance, in the set of real numbers, each number is an individuum that is never repeated in the entire (uncountable) infinite set of reals. In this case, the "individualization principle" stems from both peculiar properties of a given number and from the ordering of the entire set.

- Let us push the idea to its extreme. By adding a few orders of magnitude to the exponent expressing the probability of a given output, we could obtain any universe we wish, for instance, the universe (in fact, infinite number of them) in which Christian, Muslim (or whatever) revelation occurs by pure chance. There is certain irrationality in this idea which could suggest that some of the premises on which the reasoning is based are either false, or are badly interpreted.

6 A Remark on the Criterion of Falsifiability

Adherents of the multiverse ideology often claim that their doctrine is not a part of metaphysics because it is falsifiable. Such an assertion is possible only if one understands the falsifiability criterion in a very loose manner. Tegmark is clear about that:

> "For instance, a theory stating that there are 666 parallel universes, all of which are devoid of oxygen makes the testable prediction that we should observe no oxygen here, and is therefore ruled out by observation" [8].

The points is, however, that not every prediction that could, in principle, be compared with observation, makes a doctrine falsifiable, in the sense usually adopted in the modern philosophy of science. For instance, let us imagine somebody, before the era of cosmic missions, claiming that the back side of the Moon is painted in red with a white inscription on it that says "Coca Cola is the best". Such a claim could have never been treated as a scientifically interesting statement, although it could clearly be confronted with observation, and in fact it was, later on, ruled out by it. All those who too hastily claim that their ideas are falsifiable should first consult the huge literature in the philosophy of science concerning the falsifiability criterion. One could also express the above idea in a different way. No statement that is "non-falsifiable" can be regarded as a scientific theory, but not everything that is "falsifiable" is a scientific theory. I am afraid that many claims concerning the falsifiability of the multiverse doctrine belong to this category of "falsifiable" but not scientific statements.

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